NOVA/BEAMLET/NIF UPDATES JULY–SEPTEMBER 1996

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Nova Operations

During this quarter, Nova Operations fired a total of 314 system shots resulting in 320 experiments. These experiments were distributed among ICF experiments, Defense Sciences experiments, X-Ray Laser experiments, Laser Sciences, and facility maintenance shots.

This is the final report for FY 1996. During the past year, Nova fired a total of 1192 system shots resulting in a total of 1263 experiments. There were 981 target experiments done in the 10-beam chamber and 86 experiments done in the 2-beam chamber. There were 110 experiments conducted in support of laser science work, including precision pointing, Petawatt system activation, and miscellaneous beam propagation experiments. We fired 85 calibration shots in support of routine and precision operations.

We have started implementing smoothing by spectral dispersion (SSD) on all 10 beamlines of Nova. Hardware for the preamplifier grading table and relay lens assemblies was installed this quarter. Experiments using 10-beam SSD are planned for FY 1997.

A conceptual design for a 4ω probe beam for the 10-beam chamber has been completed. This beamline will be created by a "pick-off" mirror installed into the center obscuration of beamline 8 in the switchyard. This subaperture, 1ω beam will be propagated to the 10-beam chamber, where it will be converted to 4ω and used as a target diagnostic probe beam. Actual installation of hardware will begin next quarter.

In continuing support of the Petawatt Project, the design of the Petawatt minichamber was completed and fabrication has started. This minichamber will be used during the initial Petawatt demonstration to measure system performance and beam focusability. Installation of the minichamber is planned for January 1997. The design of the parabolic mirror system that will be used for the Petawatt beam on the 10-beam chamber has been completed. The vacuum housing and mirror gimbals for the parabola are being fabricated. The vacuum system for the Petawatt compressor chamber was also installed and activated.

The Gated X-Ray Imager #5 (GXI 5), modified to use a charge-coupled device (CCD) readout, is continuing to be used as a secondary diagnostic to provide opportunities for shakedown and activation. The GXI is also being characterized off-line to evaluate its performance using the CCD readout as compared to film. The use of a CCD camera allows immediate viewing of data following a system shot.

Beamlet

During the fourth quarter of FY 1996, experiments done on Beamlet addressed the following issues:

- Correcting the wavefront for thermally driven gas turbulence in the amplifiers and the beam tubes.
- Measuring the 3ω conversion efficiency of the 34-cm output beam, the modulation of the 3ω near-field beam at the focus lens, and the 3ω focal-spot energy distribution.
- Conducting large-area damage tests of KDP at 3ω.
- Determining the performance of Beamlet with 20-ns pulses shaped like those required for indirect-drive ignition on NIF.
- Measuring the contrast ratio and beam modulation of the near-field beam input into the main amplifier.

The Beamlet control system was modified to allow the adaptive optics system to correct the beam wavefront up to one second before shot time (T-1s) to provide a capability to correct for gas turbulence effects in the beam path. To test this system, we fired shots to compare the 1ω spot size and beam brightness with and without the T-1s system. We observed that beam quality was improved with the T-1s system but that the improvement was smaller than expected. Because Beamlet has no active cooling system, we saw a more

dominant effect from the accumulation of thermal distortion with repeated shots. Spot size and small-angle scatter increased substantially when repeated shots separated by 2-h intervals were fired. After the fourth shot, up to 15% of the energy was scattered outside of 33 μrad. The T-1s system has been used continuously since it was installed in early July.

We fired 53 shots in the 3ω campaign, 13 to activate and calibrate new diagnostics and 40 to obtain data on 3ω conversion efficiency, near-field beam modulation at the focus lens, and the 3ω focal-spot energy distribution. The new diagnostics included a 3ω dark-field imaging capability that allowed direct comparison of the scattered power fraction outside 33 μrad with corresponding 1ω measurements. The data shots were with short pulses of nominally 200-ps duration. In one series, the booster amplifier was unpumped to simulate the end of a NIF ignition pulse. In this series, we obtained 3ω power up to 2.3 TW with delta B in the booster amplifier up to 1.7 and with 200-μrad pinholes in both the cavity and transport spatial filters. We obtained up to 3.1 TW (delta B up to 2.0) with smaller 130-μrad cavity and 100-μrad transport filter pinholes. In a second series to reach powers similar to NIF SBSS performance requirements (3.5 TW of 3ω power in 1-ns pulses), we pumped the full 11-5 amplifier set. We achieved 3ω power up to 3.65 TW (corresponding to 4.6 TW for a NIF-sized beam) with 200-μrad pinholes in both the cavity and transport spatial filters at a 1ω drive power of 5.7 TW. Attempts to use smaller pinholes (130/100 μrad) with the pumped booster resulted in back reflections from the transport spatial filter that damaged the injection optics. This problem was not observed with the larger pinholes.

The large-aperture damage tests of KDP were the second series to test KDP. The samples were tested with 3-ns FWHM Gaussian pulses. During the series, Beamlet provided 3ω energies very close to those requested by the experimenters. Three samples were tested: a previously conditioned crystal, a new crystal, and a fast-growth crystal. All three samples were damaged below the expected fluence. In previous Beamlet campaigns, however, our 32-cm and 37-cm KDP/KD*P frequency-conversion crystals generated NIF output fluences on several shots without damage.

In the long-pulse campaign, we evaluated Beamlet's performance with typical pulse shapes proposed for indirect-drive ignition on NIF. The shots did not include frequency conversion but used absorbing glass as a beam dump in the frequency-conversion enclosure. We modified the pulse generation system to generate 20-ns shaped pulses. The modification in the master oscillator room (MOR) used a slow pulser to generate a long foot and used the prototype Arbitrary Wavefront Generator to provide a shaped main pulse. A cavity extension in the regenerative amplifier extended the gain window to 23 ns without affecting the stability and performance. We began the series with standard 200-μrad carbon pinholes in the transport spatial filter. We started at low energy and slowly increased the output energy up to slightly in excess of 13 kJ when evidence of pinhole closure was apparent. We changed the transport filter pinhole to a 200-μrad stainless steel conical pinhole designed to alleviate closure problems and repeated the energy ramp-up. With this design we reached in excess of 15 kJ, with no evidence of closure. Unfortunately, because of a failure in the bandwidth generation system, stimulated Brillouin scattering (SBS) generated in lens L3 caused the lens to fail and implode into the transport spatial filter, and the series had to be terminated. Rebuilding the spatial filter with new square lenses is expected to take 3 to 4 weeks.

In an attempt to resolve a discrepancy between the measured and calculated near-field profiles of the Beamlet output beam, we recorded near-field images at various planes in the preamplifier and injection optics. From these data we determined the spatial modulation at the input to the main amplifier (the calculations had assumed zero modulation at the input). Preliminary analysis now indicates that nearly all of the spatial intensity modulation is already present on the beam before input to the main amplifiers. When this is taken into account, the discrepancy between measured and calculated profiles at the output should be resolved.

NIF

This quarter, the engineering effort focused on narrowing the design options, further developing the specific designs, and updating the *Conceptual Design Report* (CDR) cost estimate based on extensive vendor quotations. The Conventional Facilities Title I Design, including the cost estimate, is now complete, and the Special Equipment Design and cost estimate 95% complete. The comprehensive Title I Design Review will begin early next quarter (October 8).

The Title I Design Reviews were delayed from the Title I Plan by one month following delay in the release of the *Programmatic Environmental Impact Statement for Stockpile Stewardship and Management* (PEIS) beyond the planned mid-September date. This time was used for value engineering of the designs and cost optimization to ensure that NIF is consistent with the minimum platform to achieve the Primary Criteria and Functional Requirements and the DOE Baseline Change Control Board Level 1 directions. The revised schedule completes the Title I Design in ten months, which is two months faster than the CDR schedule.

Planning for the Title I Design Review was completed, including completing the *Title I Design Review Plan,* which was released to Project personnel and used in detailed planning of the remaining Title I work. The

plan includes the overall objectives, organization, and schedule, as well as an outline of the agenda for the review meetings and the contents of the Design Basis books. The overall Chairman of the Review Committee was selected, as well as committee members consisting of external and internal reviewers with significant expertise in their areas of review.

In parallel with the design effort, Title I cost and schedule estimates were developed. The cost estimate establishes the project cost baseline, is used as the basis for final design and construction estimation, and provides a high degree of confidence that the Project can be completed within the established baseline. The estimate provides budget outlay (BO) and budget authority (BA) profiles, a time-phased resource requirements plan, and a commitment profile. "Bottoms-up" estimates were generated by the lead/responsible engineers based on extensive vendor quotations. These estimates will be inputted to the NIF Planning system, which is an extension of the Business Planning system developed by LLNL and has been in use for over 10 years.

Following data input and verification, a Title I cost estimate contingency analysis based on a Monte Carlo simulation built from individual system risk assessment was developed. This analysis resulted in an overall contingency allocation for the Project. Planning for the DOE Independent Cost Estimate (ICE) Review has been completed and a kickoff meeting scheduled for the first week in October; ICE Review team members have been invited to the Title I Design Review.

In Manufacturing Engineering, manufacturing assessments were provided to the Special Equipment and lead engineers in support of the Title I design and costing effort. Over 270 detailed cost estimate validations were generated. A manufacturability report was drafted for the Title I Design Reviews.

In support of completion of Title I Design, and in preparation of Title II Design, upgrade and modification of the engineering support systems, including computer-aided design and drafting (CADD) and the Sherpa Product Data Management (PDM) systems, continued. An updated version of the PDM software was implemented and tested on a selected basis. This version, which is user-friendly and contains expanded help functions, reduces or eliminates the need for training. Conversion of the entire system to the updated version was delayed to ensure noninterference with completion of Title I Design. Classes on use of the NIF PDM system continue, and administrative support personnel are providing assistance to new and less experienced users.

PDM release procedures have been updated, and training on use of the PDM system continue to reflect the modifications to documents and design drawings control. The number of documents in the PDM system increases by about 50 per week, and by the end of the quarter there were over 600 documents in the system. Also, configuration management implementation continues. Training and implementation continue on drawing release, drawing revisions, and Engineering Change Request preparation.

The engineering effort focused this quarter on continuing design iterations to simplify the systems, reduce cost, and ensure a minimum platform system that meets the Primary Criteria and Functional Requirements and the Level 1 DOE Baseline Change Control Board actions. Extensive vendor quotes and refined cost estimates were collected, reviewed, and incorporated into the Title I cost estimate.

Specific Title I Design and supporting activities this past quarter include the following:

- Value Engineering of the LTAB and OAB was completed by Sverdrup to augment the continuing value engineering efforts. The study was completed and the results reviewed and incorporated into the design.
- Parsons was awarded the Project Labor Agreement Development and Oversight contract. The process for negotiating a Conventional Facilities Project Labor Agreement has been defined to reduce the schedule risks and cost impacts due to labor disputes during the Conventional Facilities construction.
- In cooperation with Conventional Facilities, issues associated with co-occupancy of special equipment installers and building constructors in the laser bay to expedite the schedule were resolved. An integrated plan for installing switchyard structures into the building erection sequence was established. Safety planning with the NIF Construction Manager for job site operations was begun.
- A combined target chamber/building construction schedule has been finalized. The schedule interfaces suggest that the chamber be built on the pedestal rather than constructed outside the target building and moved onto the pedestal.
- The Statement of Work for the target chamber fabrication was completed. Comments have been received and incorporated by NIF procurement, selection criteria were refined, and a Request for Proposal is scheduled for release early in FY 1997. Meetings with two potential target chamber fabricators were held, and both vendors confirmed the estimated fabrication time as well as choice of material.
- Changes to the target chamber diagnostic port locations were made based on input received from the Joint Committee for Target Diagnostics, consisting of members from the participating Laboratories. A port location interface control document (ICD) was completed and approved to document the information and assure that future changes are adequately reviewed and approved.

- Design iterations in the Final Optics Assembly continue. Individual 1 × 1 Integrated Optics Modules (IOMs) were selected to simplify the system and for ease of maintenance. Work was performed on a plan for the manufacturing of final optics cells by various methods, and visits to selected vendors for building a prototype final optics cell were prepared.
- Potential effects of distributed heat sources on the thermal stability of the optical systems were addressed by the NIF Thermal Working Group. This effort is closely coupled with the Parsons team performing the computational fluid dynamics analyses and members of the LLNL Thermal/Fluids Group.
- The Optical Configuration Layout drawing set, describing optical component position, orientation, and sizes, was completed. These drawings are an important source of interface information to the Special Equipment areas.
- To enable the initiation of long-lead optics procurement, several key drawings relating to fused silica material, lens finishing, and flat finishing have progressed to a near-final design state. Several significant analyses were documented. Among these were the clear-aperture budget and component damage-threshold requirements.
- All vendor optical cost studies were received, and NIF costs updated with the most current information available. Procurement strategy for optics has been completely defined, and the final version will be released with the Title I Design Basis Book.
- Significant cost savings were realized by production engineering of the amplifier demonstration AMPLAB components for use in NIF under a TRW Master Task Agreement work order. Concepts for amplifier cooling, support, and assembly hardware that meet NIF clean assembly requirements were completed.
- Several key amplifier power conditioning drawings were completed as part of Title I design, including the modified module layout and updated capacitor bay general arrangement. Life testing began at LLNL, in collaboration with the ICF Core Science and Technology Program, on prototype capacitors from two vendors and on the prototype module at Sandia National Laboratories-Albuquerque as part of the development program. Cost estimates were completed for key components, such as capacitors, and incorporated into the Title I cost rollup.
- The Software Requirement Specifications are essentially complete. Quality Level assessments for the Integrated Computer Control System were completed and approved. Remaining ICDs were completed, except for some minor revisions.
- Precision optical diagnostics design was improved with a simplified trombone and provisions for transport mirror maintenance. The midchain sensor design was completed, and requirements were completed for the target chamber diagnostic instrument manipulator.
- In Beam Transport, numerous design improvements that simplified the system and reduced costs were incorporated. They include simplified spatial filter beam tubes and reduced thickness of switchyard structure floor gratings, saving dead weight and increasing optical stability. Additional design optimization on the periscope structure reduced its weight, and use of component commonality reduced the part count in the switchyard and target bay mirror mounts.
- Utility layouts in the target bay and diagnostic building were completed. Revised cost estimates were generated and incorporated into the Title I estimate.
- Samples are arriving to validate parts of the NIF finishing process from Zygo and Tinsley. The first Phase 1 lens was received from Tinsley and is currently under evaluation.
- The draft *Startup Plan* and a preliminary startup schedule were completed. The second draft of the operations engineering schedule was completed for project inclusion and integration. The Title I Operations modeling effort has been completed and a report drafted.
- The NIF *Preliminary Safety Analysis Report* has been completed, and related DOE and institutional comments have been resolved. Institutional approval of the report by the Associate Directors for Laser Programs and Plant Operations has been received. DOE has concurred and will provide the *Safety Evaluation Report*, which gives final concurrence in early October.
- The PEIS has delayed the Notice of Availability to late October 1996 at the earliest. An analysis of delay impacts was prepared for DOE. The NIF *Technical Analysis* document, which includes justification and site comparisons, has been completed and is ready for publication.
- The environmental permit strategy was reviewed with DOE/OAK and DOE/HQ. All DOE comments to support the *Safety Evaluation Report* have been resolved.
- The *Quality Assurance Program Plan* (QAPP) was revised for Title II design, equipment procurement, and construction. Laboratory Project and DOE approval have been received. Eight Project procedures to implement the QAPP update were revised or prepared.

The Title I Design Reviews will be done time-phased, starting with the schedule critical path Conventional Facilities (including the Laser and Target Area Building, Optics Assembly Building, and site preparation) followed by three Special Equipment review segments. DOE actions, including determination by DP-1, with EH-1 concurrence, to proceed with limited Title II design concurrent with completion of the final PEIS and Record of Decision (ROD), will minimize the near-term adverse impact to the Project.

To maintain progress and keep the Project on schedule requires an ROD by mid-December 1996. Other activities that will be completed next quarter, leading to beginning of site preparation in mid-March 1997, include completing the ICE Review and preparing packages for the DOE Level 1 Baseline Change Control Board meeting in mid-December.